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THE LIGHTING OF PUBLIC BUILDINGS

By W. T. F. SOUTER *(Fellow)*

(Paper read on Tuesday, November 9th, 1943.)

Before commencing with the subject of this paper, a few explanatory remarks in regard to its conception may be desirable, as it will be generally appreciated that the range of buildings is too great to be encompassed in a detailed manner in one paper.

As has been announced, the Illuminating Engineering Society has convened a committee to consider post-war lighting in relation to reconstruction, with the ultimate purpose of stimulating interest in good lighting. At its inception, the Lighting Reconstruction Committee elected a select panel to prepare recommendations for the lighting of certain public buildings such as schools, libraries, museums and galleries, hospitals, public halls, and swimming baths.

Each member of this panel, represented by Messrs. F. P. Bentham, H. G. Ellis, R. H. Finch, C. W. M. Phillips, H. W. Pierce, and E. Stroud, prepared a paper on one of the above items, and these recommendations were then collated and submitted to the main reconstruction committee.

It has been suggested that much of the material acquired in this connection would provide a suitable basis for a paper which would be of interest to the Society and serve as a platform for useful discussion.

The author wishes to record his appreciation of the data placed at his disposal by the aforementioned members, and trusts that they will appreciate that the treatment and practical illustration of the subject matter has necessarily introduced opinions which are personal to the author.

Post-war lighting technique must be influenced by those principles of adequacy and suitability which we have developed in the light of our past experience, and the views expressed are therefore representative of good lighting practice at the outbreak of hostilities.

Artificial illumination is an essential service in every public building, and each citizen is entitled to expect the provision of adequate and suitable lighting in those buildings erected for his benefit and welfare, and for the upkeep of which he has to contribute.

Whether it be the grand civic building or the modest village hall, each has the same relative value to its own community, and artificial lighting plays an important role in the full realisation of the facilities which each building affords.

Apart from the purely utilitarian considerations of illumination for the primary purpose of seeing, it has become recognised that carefully designed lighting can enhance the furnishing and decorative scheme promoting an atmosphere complementary to the character and purpose of the building.

How often have we experienced that chilly and inhospitable sensation on entering a public building, despite the excellent furnishing and obvious efficiency of the heating system, only to find that the psychological impression has been created by an ill-conceived and unimaginative lighting system? When we compare such installations with those in which the lighting has been skilfully designed to convey bright and cheerful surroundings, then the value of this aspect of lighting immediately becomes self-evident.

In order to arrange a convenient method of presentation, the buildings have been grouped according to their facilities for education, welfare, and recreation.

Schools.

Schools rank high in importance from the national standpoint, in that they prepare the younger generation for their responsibilities as the citizens of to-morrow. The scope and nature of the training received in school establishments can differ considerably, but in all of them teaching is mainly effected by visual methods, requiring good standards of lighting, both natural and artificial.

It may be truly said that the eye is one of the principal gateways to knowledge, and the lighting should be such

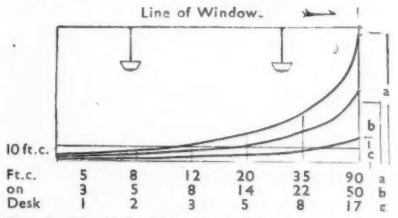

Fig. 1. Daylight illumination in classrooms, on typical bright (a), cloudy (b), and dull (c) days illustrating need for supplementary artificial lighting in areas remote from windows.

therefore, that it will be an aid to vision, enabling the student to readily discern unfamiliar characters without sense of visual discomfort.

Whilst investigations have shown that adequate lighting will improve the standard of scholarship and general receptivity of the students, there can be no question that inferior lighting can not only retard education, but also adversely influence their health—a factor which has often been stressed by medical authorities.

Although the fenestral elevations of more recent school buildings has improved the daylight illumination in classrooms, the vagaries of our climate still necessitate supplementary illumination on many occasions, particularly in those areas of the classroom which are more remote from the windows. Thus, the artificial lighting should blend with the daylight, and those units serving such areas should be separately switched, or alternatively controlled by equipment automatically operated by light sensitive cells when the daylight falls below a predetermined value.

It is important to remember that the majority of the schools also provide facilities for evening classes throughout the winter months. The students who attend such classes have already completed a normal day's work at their various occupations, and they approach their studies with some degree of mental and physical fatigue. Not only is it essential that the illumination will be adequate to allow them to undertake their tuition without the additional handicap of conscious visual strain, but every effort should be made to furnish a pleasant environment which will maintain their interest and inculcate a sense of alertness and well being.

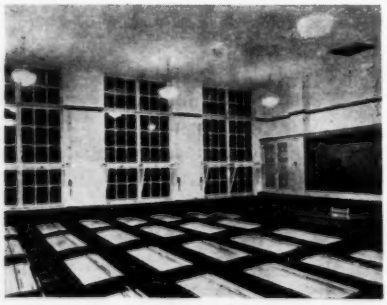

Fig. 2. Classroom. Semi-direct units having low brightness, in conjunction with light walls and ceilings, promote good visibility and a pleasant environment.

The main considerations for good lighting in *Classrooms* and *School Premises* may be stated as follows:—

1. Equipment which will afford suitable light distribution, employed in such a manner as to ensure adequate diffusion with freedom from objectionable shadows. The positions of the lighting units should be so arranged that unavoidable shadows are soft and luminous and do not interfere with the visual task.

2. Reasonable uniformity of illumination should be maintained, and in working areas it is recommended that the minimum value should not be less than 75 per cent. of the maximum illumination.

3. Complete freedom from any glare which impairs visibility, whether direct from the light source or reflected from shiny surfaces on walls or fixtures. Desk tops and other surfaces likely to give rise to reflected glare should be finished with a matt texture. In order to attain a suitable standard of performance in this connection, it is recommended that no luminous portion of the lighting fitting is lower than 9 ft. above floor level, and that the surface brightness at different angles of view should be limited to acceptable values.

Fig. 3. Example of American classroom lighting. Indirect reflectors with silvered bowl lamps provide excellent diffusion with freedom from direct or reflected glare.

4. The provision of light, suitable in both quantity and quality for the visual task. The light source should be free from flicker and the spectral

range should permit of reasonable discrimination of colour.

In *Classrooms*, a maintained illumination of 10-15 ft.c. at desk level is recommended, with supplementary illumination of the blackboard in order to focus attention and improve perception.

Where direct lighting units are employed, it is important that their light distribution and spacing should be such that each part of the working plane receives light from more than one fitting. It is necessary, furthermore, that such units will allow sufficient upward light to ensure ceiling brightness and reasonable uniformity of illumination on the surrounding walls.

It cannot be too strongly emphasised that the general appearance of the room should be bright and attractive and that these amenities are also dependent on suitable decorations, apart from lighting considerations.

In lecture halls and classrooms where the floor level is stepped up progressively towards the back of the room, it is important to consider the lighting units in relation to persons seated at the most elevated positions, and to provide for an unobstructed view of the blackboard with freedom from direct glare.

The lighting to serve the blackboard must be such that direct glare and specular reflection on the board surface cannot arise. It is important to avoid reversed contrast between the blackboard and its immediate surroundings, and it is in this connection that "chalkboards," having a matt cream surface for use in conjunction with coloured chalks, offer certain advantages.

The lighting of *Assembly Halls* has to be of a general purpose nature, with sufficient flexibility of operation to cater efficiently for the various functions for which the hall is employed.

Fig. 4. Assembly Hall, George Watson School, Edinburgh. Multi-panel ceiling fittings, having access from above, form part of the architectural treatment of the building.

Such places are frequently used as overflow class-rooms and for examinations; the lighting arrangements should therefore permit of the attainment of good class-room lighting standards. Most school halls now provide facilities for amateur dramatics and lantern lectures requiring more subdued illumination, and where such halls include a gallery care must be taken that fittings do not interfere with the view of the stage or give rise to glare conditions.

The architectural treatment of these halls, particularly in the modern schools, is often both dignified and impressive, and in planning the lighting system it is incumbent on the designer to consider the aesthetic as well as the functional aspects.

The illumination requirements in laboratories are similar to those stated for classrooms. The apparatus employed for many experiments is frequently of a bulky nature, reaching high above bench level, with recording instruments at many positions and in different planes.

These conditions require good vertical illumination and diffusion in order to allow of detailed observation and freedom from obscuring shadows. Light sources affording colour correction will facilitate observation during experiments involving colour discrimination, such as titration and chemical analysis.

Craft Rooms and Engineering Workshops require careful treatment, and it cannot be too strongly emphasised that the lighting in these workshops should be in every way comparable with the best standards practised in our modern industrial plants.

The recommendations in the I.E.S. Code have been established as necessary to enable even skilled operatives to perform their various tasks with efficiency and safety, and those same standards are therefore equally essential for students who are less adept and confident in their manipulation of the machines and tools.

It should be borne in mind that these students are potential factory executives, and so need to be educated to appreciate the vital part that lighting plays in factory production and welfare. An excellent opportunity also presents itself for demonstrating the advantages of light surroundings and the introduction of colours for the treatment of machinery and fixtures.

In *Art Rooms and Drawing Offices* it is

very desirable that the occupants should enjoy shadowless lighting on their drawing boards, preferably of a quality akin to daylight both in colour and diffusion.

A value of 15-25 ft.c. is advocated and totally indirect units or fittings employing fluorescent tubular lamps find an ideal application in these rooms.

Special treatment is necessary for the lighting of the models, strong directional lights of an adjustable nature being employed to obtain the correct depth and gradation of shadows for true perspective and artistic effect.

Gymnasiums require well-diffused lighting and a minimum value of 6-10 ft.c. is desirable, furnished by fittings of robust design placed close to the ceiling to avoid accidental damage.

Gymnastics and indoor ball games call for speed and accuracy of vision, and the standard of performance, and often the safety of the individuals, depends on precise timing, which can only be gauged under conditions affording maximum visibility. Inadequate illumination, deep shadows, direct or reflected glare can be the direct cause of accidents and broken limbs, and the lighting should therefore be designed to remove such hazards.

Where badminton, tennis, and similar games are practised it is preferable to provide a separate lighting system employing units on the sides of the court, as overhead units are apt to create glare under such conditions.

For *Corridors and Stairways* a value of 4-6 ft.c. is recommended to permit ease of movement and safety of students who are hurrying from one class-room to another, and who, in the buoyancy of youth, are inclined to negotiate the stairs in a rapid and unorthodox manner.

The staircase lighting should be planned to give clear definition of the risers and treads, together with freedom from shadow and glare when descending flights. Lighting units having low surface brightness should be located on each landing, and a distinctive colour or pattern on the front edge of the treads will improve perception.

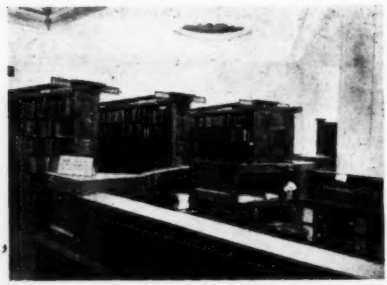

Fig. 5. Luton Library. Shallow trough units recessed in top of bookstacks provide indirect lighting and shadow free illumination of the book spines.

Public Libraries

The tremendous strides which have been made in the science of illumination and the art of printing have done much to make reading a pleasure and a universal habit. People of all classes and all ages readily avail themselves of the many facilities which a public library affords, whether it be for recreational literature, educational works, or a desire to be well informed of local, national or international affairs.

Of all the buildings erected for the purpose of disseminating knowledge, surely the library is most dependent on adequate lighting, for the public must rely entirely on their ability to see in their search for the books and information they require. One might draw a comparison with the motor-car, which will greatly increase the scope of one's activities, but becomes a rather useless possession without petrol to supply the motive force.

In general the lighting installation in a library should be influenced by the following basic considerations:—

1. Sufficient light correctly related to the vertical or horizontal plane as the situation demands.

2. Avoidance of exposed or bright light sources in the field of normal vision, and freedom from excessive contrasts and shadows.

3. The prevention of reflected glare from specular paper surfaces.

4. Planning to harmonise with the architectural features of the building to produce a satisfactory and pleasing appearance.

News Rooms and Magazine Rooms require well-diffused and even illumination to a value of 10-15 ft.c. in areas devoted to reading, the illumination design being such that comfortable seeing conditions exist. Special care is necessary to prevent annoying shadows on newspaper slopes, and the possibilities of reflected glare from the glazed pages of illustrated journals should be given particular consideration.

In assessing the lighting requirements in *Reference Rooms* it is well to remember that many of the books and manuscripts are old and faded, frequently

having small print rendered indistinct by continual handling, presenting a severe reading task, particularly when studied for prolonged periods.

Furthermore, the more habitual seekers after knowledge often suffer from defective sight; spectacles and a studious nature are an all too common combination, especially with advancing years.

In these circumstances an illumination of 15 ft.c. should be considered a minimum, and where it is not economic to provide such a value by diffused general lighting, the provision of well-shaded local table standards is advocated.

This latter arrangement of local supplementary lighting offers certain advantages in that a measure of contrast between the reading area and the surroundings promotes a sense of isolation

Fig. 6. Weir Hall Library, Edmonton. Effective lighting treatment by ceiling type panel units where laylights preclude the adoption of an indirect system. The design of the lower shelves in bookstacks is a point of practical interest.

which is favourable to concentration and study. But such a method requires suitable planning, however, to avoid excessive contrast between the brightness of the pages of the book and the immediate vertical surfaces within the normal range of vision.

The *Lending Department* demands special attention to the light distribution in order to avoid shadows which might hinder the reading of the book titles. A vertical illumination of 2-4 ft.c. on the book spines should be considered a minimum, and while the general requirements may be met by the provision of a horizontal illumination of 6-10 ft.c., this value can be increased with advantage for the clerical work at the reception desk.

Where direct lighting is employed, and a number of persons are in close proximity to each other and to the book stacks, it is extremely difficult to prevent shodows on the books, particularly on the lower shelves.

With the ever-growing popularity of the open access system this problem has acquired a more serious aspect, and experience has shown that an indirect lighting system overcomes the difficulty in a very satisfactory manner.

Indirect lighting units, which can be readily recessed and concealed in the top of the book stacks, afford well-diffused and shadowless lighting in these circumstances providing the ceiling is suited to such treatment.

Illuminating engineers will agree that it is most refreshing to find such accommodating lighting positions already at their disposal, particularly when we consider our usual difficulties with sprinkler systems, ventilation ducts, laylights, beams, and panelled ceilings, all of which vie with one another to make our ideal lighting positions impracticable.

This method has the further advantage that the layout of the book fixtures can be modified or supplemented without undue interference with the lighting arrangements, whereas a direct lighting system would require complete replanning and possible disfigurement of the ceiling.

While considering public buildings which offer educational facilities we must include *Museums and Art Galleries*, which display the industrial, artistic, and cultural progress of the nation.

Pictures, sculptures, and other works of art appeal so entirely to the sense of sight that it would be an act of vandalism to do other than provide the correct gradation of light, shade, and colour required for the full appreciation of each exhibit.

Picture Galleries

Apart from the fundamental requirements of adequacy and uniformity of illumination on the exhibits, the principal consideration is the avoidance of reflections on the glazing of the pictures. Where such reflections can hinder the appreciation of the subject and in acute cases entirely dazzle the observer, attention to the following points will reduce this disability to limits where it is no longer objectionable.

1. **Reflected** images of the light

source can be eliminated by siting the lighting units in relation to the pictures so that specularly reflected rays are directed away from the eye of the observer. It is essential that each light is considered in relation to all the pictures in the room, especially in long galleries where pictures are frequently hung on the end walls as well as on the sides.

2. The walls on which the pictures are displayed should have a matt texture of neutral colour to avoid specular reflection and simultaneous contrast in colours between the pictures and background.

Fig. 7. Charlemont House Art Gallery, Dublin. Lighting troughs arranged in ceiling panels illuminate wall space and are screened from central viewing area by ceiling beams.

3. Reflections of observers can be reduced to a point when they are scarcely noticeable by restricting the level of illumination in the public space so that the brightness of their reflected image is low compared with the brightness of the picture.

4. Where only one side wall is used, reflections of opposite walls can be subdued by adopting a colour which approximately matches the average reflection factor of the pictures themselves.

In such cases where the limitations of hanging space necessitate pictures suspended on opposite walls, the cross reflection of pictures can only be eliminated successfully by the employment of a partition down the centre aisle.

Museums

The statuary and showcase displays in museums may be instructive and interesting, but one could hardly say that their general atmosphere is exhilarating. One sometimes gains the impression that Rip Van Winkle could remain there undisturbed, and that on awaking he would find little amiss with his surroundings. It should be the aim of the illuminating engineer, therefore, to introduce a bright and cheerful aspect in the lighting which will dispel dull and dreary dimness.

Sculptures and statuary are studies in light and shade, the correct gradation of which affords the visual appreciation of form in three dimensions.

In the illumination of such displays it is therefore desirable to provide well-diffused light having a dominant source or direction in order that the exhibits can be positioned in relation to the directional component to achieve the most satisfactory effect. Where isolated but important sculptures are arranged in conjunction with showcases and exhibits requiring general diffused lighting, the necessary effect of light and shade can be obtained by carefully located spotlights or floodlights, but such equipment must not be obtrusive or mar the architectural features of the building.

Reflections from the glazing of showcases are always a problem and can usually be overcome by employing totally indirect lighting in conjunction with internal lighting of the showcases.

The illumination values on exhibits in both picture galleries and museums should be a minimum of 10 ft.c., and it is obviously desirable to employ light sources which closely approximate to daylight in their spectral quality. This latter factor is particularly essential in those rooms in which artificial illumination is the sole method of lighting tapestries and pigments possessing delicate fugitive colours which would quickly fade when exposed to natural daylight.

Hospitals

Now that we have considered those buildings having educational appeal we will next deal with the hospitals which safeguard the health and life of the citizen, and where good lighting is an all-important factor.

Scrupulous cleanliness can only be maintained when shadows and dark corners are dispelled and everything is clearly visible to those whose duty it is to attend to this vital routine.

The general lighting requirements in the greater part of the hospital can be planned on the well-established principles of good indoor lighting technique. Consideration should be given to the provision of secondary, low, night illumination in the wards, and the desirability of local bed head lights which allow of individual attention to patients during the

night without disturbing the remaining occupants of the ward.

In the *Operating Theatre* the lighting system plays a vital role, and the success or otherwise of an operation may well depend upon the reliability and efficiency of the illumination.

The surgeon must be provided with conditions which will stimulate the

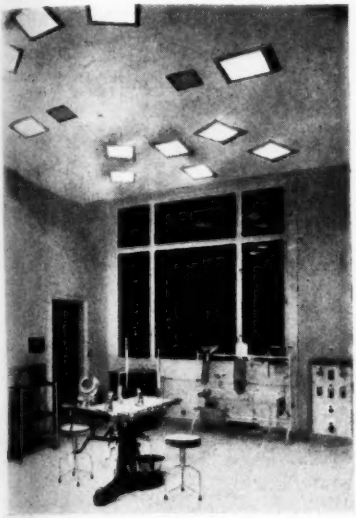

Fig. 8. Operating Theatre. Great Westminster Hospital. High intensity shadowless lighting on Operating Table by a system of prismatic panels recessed in ceiling.

maximum visual acuity in order that the eye and hand can be perfectly co-ordinated to the most skilful and delicate task. Here at least few will dare to argue the economics of illumination and expenditure when the preservation of lives may be endangered by such considerations.

An illumination of 200 ft.c. over the operating table can be considered a minimum rather than a maximum, and the fundamental features in regard to quality are as follows:—

1. The avoidance of glare conditions as far as is practicable.

2. The provision of maximum light diffusion so that unavoidable shadows are soft and luminous.

3. Light sources affording good colour quality with freedom from flicker and stroboscopic effects.

4. The heat dissipated by the lighting fittings should not be such as to cause discomfort to those in the vicinity of the units, or injury to the patient.

5. The system should embody a satisfactory secondary lighting circuit which will come into immediate operation on failure of the principal source of illumination.

These conditions may be met by the provision of an adequate number of ceiling units, the disposition and light distribution of which ensure that each part of the operating area receives illumination from widely distributed light sources. Alternatively, the same principle of convergent light rays may be obtained by a single light unit of large diameter and special optical design which can be quickly trained to any part of the operating area.

The general lighting of the operating theatre and annexes should be well diffused and maintained to a value of 30 ft.c. to avoid adverse contrast with the high intensity in the operating area.

Municipal Buildings and Public Halls.

The Town Hall or Guildhall is the pulse and directing force in any large community, dealing as it does with the administration of local affairs and development. In every progressive town this edifice is therefore a matter of civic pride, either by its historic associations and architecture, or by virtue of impressive modern construction and the amenities it affords. The Guildhall and the Mansion House and their important role in the everyday affairs of the City of

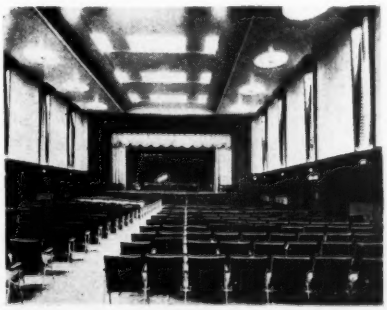

Fig. 9. Hornsey Town Hall. Artificial laylights in conjunction with indirectly lighted circular ceiling coves provide an attractive form of primary and secondary illumination. Window screens illuminated by reflectors concealed behind the pelmets afford an interesting feature.

London provide a good example of the former type, while more recent buildings having their own particular architectural appeal are so numerous that we are all well acquainted with them, although we are perhaps a little more appreciative of the old building when we are called upon to share the costs of the new.

Halls which are devoted to public functions have to be adapted to many purposes, and the lighting system has therefore to be flexible to fulfil adequately each different requirement.

Public Meetings and Concerts.

While the design of the auditorium lighting will be developed to harmonise with the general architectural scheme, care must be taken that there is unobstructed vision and freedom from glare when viewing the platform. The lighting of the latter should be planned on stage lighting practice, although the intensities and equipment need only be on a modest scale. An illumination value of 10-15 ft.c. will meet most requirements in this direction, with approximately half this value maintained in the auditorium. While it is important for the audience to see the features of the speaker it should be remembered that it is equally important for the latter to observe his listeners in order that he can discriminate between rapt attention and a state of somnolence.

During musical performances the conductor must be clearly visible to the orchestra or choir, and the audience should be able to focus attention on his movements without conscious effort.

During *theatrical performances* the most satisfactory dramatic effect and focus of attention is secured by reducing the illumination in the auditorium to the lowest level consistent with safety of movement, while at interval periods the value should be increased to allow of casual reading without a sense of discomfort.

Stage lighting technique has reached a high order of merit, and the most simple of stage settings can be rendered attractive by the skilful use of colour lighting. The lighting plot makes a vital contribution towards the correct emotional atmosphere throughout the play.

Fig. 10. Colston Hall, Bristol. Semi-indirect Lighting by wall mounted prismatic panel fittings arranged to project light flux towards ceiling. Illumination of concert platform augmented by concentrating units recessed in ceiling.

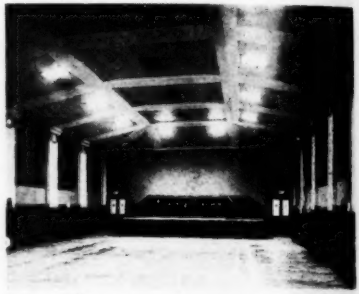

Fig. 11. Lighting systems employing built-in ceiling fittings convey a sense of spaciousness in halls having modest proportions and relatively low ceiling heights.

and the stage lighting equipment should therefore be as comprehensive as possible in order that the desired effects can be achieved.

Battens, footlights, and wing floods, having dimmer controlled colour circuits, provide the basic lighting, while stage and auditorium spotlights are employed to secure dramatic effect and to improve the facial illumination. In halls of this nature, where performances are relatively infrequent, it may prove more economic to instal the basic requirements and hire additional equipment as required, but suitable provision should be allowed in the installation of plug points and switchboard dimmer circuits to ensure the safe and efficient operation of such apparatus.

Dancing and ballroom functions require lighting effects which have a pleasing psychological appeal, creating an atmosphere of gaiety and relaxation.

Soft, well-diffused illumination, the introduction of colour, and suitable variation of intensity over the floor and seating area will assist in the promotion

of such conditions. It is necessary to remember, however, that the predominant colour lighting effects must be kind to both the complexions and dresses of the fairer sex, as the success of such occasions is very dependent on their satisfaction of these artistic considerations.

Spotlights on, or close to, the ceiling will further enhance the spectacular effect of certain dances, and are essential for focusing attention and achieving the desired effects for exhibition dances and displays.

Lighting and Architecture.

In the past, the lighting engineer has been to a certain extent handicapped by the necessity, so often paramount in old buildings, of conforming to historic traditions and making use of existing chandeliers and other lighting equipment of period design.

The ravages of war have altered this position, however, and when peace reigns once more, new buildings, modern in their conception, will arise, providing a virgin field and unlimited scope for the lighting designer.

In the illumination of such buildings it will be essential, however, for the lighting system to be considered at the earliest stages; too often in the past opportunities for original and effective lighting treatment have been lost due to the fact that such considerations have been left until the building has been nearing completion. Only by the close co-operation of the architect and the lighting engineer at the drawing board stage can the true functional and artistic merits of the lighting system be mounted into the architectural design, so that it becomes part of the whole rather than so many disturbing appendages. Happily this close association of the two professions has already been established in the years immediately preceding the outbreak of war, and the present-day importance of artificial lighting as the result of the prevalent black-out conditions in vital buildings has engendered a mutual respect and a wider vision of the possibilities arising from such team work.

If this co-operation has been slow of achievement, is it not possible that it was partly due to the fact that we were slow in bridging the gap between the purely functional and the artistic application of lighting, leaving the architect with a sense of frustration and finally in a state of apathy? Have we not been over conservative and bound by convention in the design of our lighting equipment, slow in grasping the possibilities which improved and more powerful light sources have offered?

In the earlier days of weak illuminants, pendant fittings were a necessity for reasonable lighting efficiency, and little discomfort from glare was experienced as a result of the low brightness of such sources. Since that period there have been tremendous developments in the efficiency of light sources with corresponding increases in their intrinsic brilliances, yet we still harness these illuminants to pendants so that to-day we find our greatest problem is the avoidance of glare and the attainment of good visibility.

We seek to cure these troubles by enclosing the sources in large translucent units in order to achieve a low brightness which will not offend the eye, and then conscious of their obtrusiveness we endeavour to make them more decorative, just as our grandmothers did with their crinolines. It is inevitable under these conditions that we are immediately conscious of the lighting fittings when entering the room, but surely the criterion of good artificial lighting should be that it is akin to daylight and that we are not directly aware of the manner in which it is effected.

The wide range of efficient light controlling media now at our command presents us with the opportunity of installing our lighting units at ceiling level, at which position they become an architectural feature, as opposed to many spidery pendants of doubtful beauty. Such treatment would be in harmony with modern building construction, which demands clean unbroken lines and, furthermore, does much to mitigate our own problems in respect of glare and visibility.

Many installations of this type were introduced in the more recent pre-war buildings with very successful results, and it is the author's opinion that the progress of this system will be influenced and accelerated by future developments of the fluorescent discharge lamps, as these long tubular sources are more easily accommodated in ceiling fixtures.

It is not suggested that ceiling type units are the architect's Utopia or the cure of all lighting evils; there will still be occasions where the construction, architectural design, or special lighting requirements are such that pendant units will afford the most effective and efficient treatment. Nevertheless, the advantages and possibilities of the former are such that it deserves wider attention than it has enjoyed in the past.

In conclusion, the author wishes to thank the members for their kind attention and patience with his maiden paper

to the Society, Mr. J. S. Dow for his helpful guidance during the preparation of this paper, and the E.L.M.A. Lighting Bureau and Holophane Company for the lantern slides which have been put at his disposal.

Discussion.

Mr. C. W. M. PHILLIPS said this was the first time that one of the Reconstruction Committees had reported back direct to the Society through a paper of this kind, and as a member of this particular committee he congratulated the author on the confident manner in which he had handled such a wide field. In connection with school lighting—in which his own interests lay—he said that post-war reconstruction offered a splendid opportunity for the illuminating engineer. There were some 5,000,000 children attending elementary schools, which numbered some 20,000, belonging in part to local authorities and to other bodies such as Churches. Many of these schools were very old, and he asked the author if a survey had been carried out here in order to gain an impression of the standard of lighting in our elementary schools. Also, could the author give any comparative costs of lighting installations against other school services. He had seen figures for 1935 which showed that the cost of conducting one school in London was £21 3s. 2d., of which £12 4s. 10d. went in salaries, and £3 8s. 11d. went in rent, rates, taxes, insurance, fuel, cleaning, stationery, and repairs, so that it was reasonable to assume that lighting did not represent a very large part of the cost of operating that school. Data was also required of the relation between eye-strain, due to inefficient lighting, and educational progress. A paper by the School Medical Officer at West Ham indicated that where the lighting in schools was said to be good, 5 per cent. of the children suffered from eye-strain, but the percentage was 10.4 where the lighting was said to be bad. The Americans had done a good deal of work on this subject, and the Professor of Education in Missouri, where part of the Lafayette School was set aside for experiment, showed that in classrooms where there was really good lighting the educational progress was some 2 or 3 per cent. better for quite a large number of pupils. Reports on this matter had been published in America in 1918, 1924, 1932, 1938, and 1940, and the answers to a questionnaire sent out to 20,000 schools showed that 12 per cent. of American schools had lighting installations in keeping with the American I.E.S. School Code, that 66 per cent. of the new schools built in 1938 met the Code, and 67 per cent. of the relighting jobs carried out in that year also met the Code. From 1924 onwards the American School Code had been issued in association with the American Institute of Architects and the American Sanitary Association. Therefore, this paper might be followed up by the formation of a Study Group to look into school lighting and allied problems, and there should be representatives of the architectural profession on such a Group, and also of the local educational authorities.

Mr. P. V. BURNETT said that as an architect he agreed that there should be co-operation between illuminating engineers and architects, and that there should be mutual respect for one another. It should be appreciated that the architect had many other things to think of in designing a building than artificial lighting, and one of them was natural lighting. With regard to schools, it was very disturbing to know how many children had defective eyesight in this country. It seemed that whereas 8 per cent. of children entered school with defective eyesight, no less than 25 per cent left school with defective eyesight. Of course, it was very difficult to say how much of that was due to lighting, how much to the visual task which the child was asked to perform, and how much defective eyesight there would have been if the children had not gone to school at all. Here was a large field for research which had been utterly neglected hitherto. He was not at all satisfied that industrial research methods could be applied to schools, or even that the results of industrial research were being interpreted correctly, viz., that better lighting improved output and efficiency. We did not know whether that was so over a long period, and from discussions with factory managers he had the impression that improved output might only be obtained at the expense of shorter working life. In other words, the working life of the operatives might be reduced through making them work at too high pressure. If that proved to be so, then higher intensities of light might make the percentage of children leaving school with defective eyesight even higher than the 25 per cent. he had mentioned. This was a matter which should be gone into thoroughly before further rules and regulations were made to improve the standard of school lighting.

Mr. F. C. SMITH said that the lighting of schools called for skill and careful

design since children were called upon at a comparatively early age to perform a variety of exacting visual tasks which increase in severity as the pupil advances through the school. At some time during the school years pupils have to read comparatively fine print, such as the symbols found in mathematical textbooks, work in the science laboratory and art school, and to do some hand work such as sewing or manual training. The classroom, laboratory, art school, or manual training centre each call for specific treatment by the illuminating engineer. He believed in the future that higher intensities would be demanded for classrooms than was the practice today, and with these higher values would come problems which must be solved satisfactorily if these values are to be applied with acceptance. As a chemist he felt it very important to have laboratory lighting which corresponded very closely to daylight in colour.

He would not, as other speakers had suggested, care to base the case for improved school lighting upon a correlation between standards of lighting and educational progress. Many of those who attended the International Congress in Holland came away a little cynical with regard to the rather sweeping deductions made from certain tests of these characteristics which were reported to the Congress, because it was clear that all the variables were either not recognised or, if recognised, were not correctly weighted. Personally, he did not know how educational progress could be measured with sufficient precision for this purpose. He believed there was an unanswerable case for improved lighting, even if no direct improvement in educational progress could be related to the better conditions. Good lighting should not stand or fall on such arbitrary tests.

Referring to street lighting, the speaker said it was often sought to show that the accident rate fell off with improved lighting, but it was equally true that accidents had been known to increase with a higher standard, since drivers were inclined to speed up in consequence of easier seeing. There were times when our inborn sense or intuition was possibly a safer guide than the pseudo-scientific investigation in which all the factors were not known.

The problem of classroom lighting in the future would probably be to arrange for an intensity of 15 ft.c. at desk level with ceilings of about 11 ft. height, and to secure this result without introducing high brightness sources in the field of vision.

Mr. GEORGE SMITH spoke of experiments in libraries just before the war, and said that in temporary buildings since then there had been a tendency to use the tubular type of light source. He asked what was the best form of lighting in the case of the big book stack running from floor to ceiling.

In the case of the National Gallery, he said that although overall illumination was quite good, it tended to be monotonous, and in new work it might be desirable to think in terms of different lighting for the different schools of painting. In Museums it was necessary to light the exhibits and not the room, but very often the lighting was arranged first and the exhibits were put in afterwards. In the Geological Museum, the special case lighting using non-reflecting curved glass was generally good, but it was necessary to get into a definite position in front of the cases before one could see the exhibits properly. In the case of hospitals it had been found possible to do with lower values of illuminations than those mentioned in the paper. It did not appear that high intensity in itself was always a thing to be welcomed. Another problem for the lighting engineer was that architects were designing buildings with lower ceilings, presumably on account of reduction in cost, and for these cases fluorescent lighting was probably the answer. The proper screening of the light source was essential. Finally, he advocated the holding of more joint meetings and discussions between architects and lighting engineers.

Mr. E. STROUD said that he would like to support Mr. Souter with his paper, inasmuch as he was chairman of that Select Panel which he mentioned and who prepared a number of individual recommendations for the lighting of various forms of public buildings, which formed the basis of that submitted to the Main Reconstruction Committee. The Panel were very enhusiastic and put a lot of work into their papers, but he believed that the whole matter had now been transformed so that the final pamphlet bears little, if any, resemblance to the original.

Mr. Stroud said that Mr. Souter's paper was very refreshing, in so far as it took them at one bound to the future, he hoped early, when war would be no more and we could busy ourselves with

everyday lighting problems. Mr. Souter pleaded for the bright and cheerful interior, with unobtrusive lighting fittings.

One could easily foresee the importance of the fluorescent tube in future schemes for the lighting of public buildings, and it would seem that "built-in" panel lighting should be the general trend. This brought him to consider the main lesson to be learned from the paper—that the architect should plan his artificial lighting with his original building, and pleaded for close co-operation between the architect and lighting engineers.

Mr. R. O. ACKERLEY said that in listening to the paper he had wondered whether we were quite sure what we were doing, and whether a great deal more investigation was not necessary. From the slides shown by the author it did not appear that local lighting of blackboards was altogether satisfactory. In one case the blackboard looked almost white! As regards the lighting of staircases one slide showed the risers and the tread illuminated, but it was better that the risers should cast a shadow half-way across the tread so that a pattern of light could be seen when one was going up or down and the edge of the tread plainly seen. In the case of directional lighting for sculptures there was a difficulty in getting a concentrated beam of light without getting a flood of light in the background, and it was necessary to diaphragm the light so that none was lost in this way.

Where did the author get his figure of 10 ft.c. for lighting the tops of pictures? The illumination on the walls of the National Gallery was between 6 and 8 ft.c., and that was arrived at not because the Office of Works was economising, but because they had tried illumination values very much above and below those figures, and the general consensus of opinion was that from 6 to 8 ft.c. gave the best result. Was there any scientific, or even empirical, basis for the correctness of the author's figure of 10 ft.c.

A great deal of experimental work might be done by the Society with regard to operating theatres. Many surgeons took a great interest in lighting and held the view that the lighting in the remainder of the theatre should be extremely dim, with high illumination on the operating table. Personally, he did not quarrel with 30 ft.c. for general lighting, and he wondered whether the view of surgeons to which he had referred was right. He wondered whether 500 ft.c. on a 1-ft. object was as good as was done in one London hospital, where they used fluorescent tubes to give 250 ft.c. over an area of about 5-ft. square. Here, again, there should be investigation. And did we know enough about the lighting of hospital wards? That was a difficult question, and the solution would only be obtained by lying on the back in a ward for long periods as the patients had to. Perhaps the next time an illuminating engineer had the misfortune to be in hospital he would carry out some investigation of this kind!

Two points had not been mentioned by the author, and they had special application to public buildings. One was that buildings in charge of public authorities should set an example. The second point was that it should be impressed upon them that their buildings should have adequate intallations with suitable maintenance. There should always be a lighting maintenance man in charge of such buildings, not merely a caretaker but a qualified man whose job it was periodically to examine the lighting installations owned by a particular authority and, if necessary, give instructions to the caretaker to do what was necessary. Such a man should, of course, know something about lighting and have the necessary equipment to carry out his task

Mr. L. G. APPLEBEE regretted that the paper had omitted the lighting of swimming baths. He referred to the indoor type that catered for swimming galas. He had yet to see the bath that was illuminated for the purpose for which it was built, i.e., *swimming*. Its seating was generally arranged for spectators to witness swimming contests, yet there was very little attempt to light the "show." In many cases the lights were quite suitable for the usual winter bath activity or a two-shilling dance on Saturday night.

The under-water lighting was a very good "stunt," but was not liked by many racing swimmers, who at galas had been known to ask for the lights to be switched off—particularly so in the case of the man who has, by the luck of the draw, to swim right up against them. The swimming area should, for serious racing, be illuminated from above the fittings, providing a sharp cut-off at the edge of the bath so as not to flood the

spectators as well. There also seemed to be a need for special overhead lighting when acrobatic diving was taking place.

In regard to the public halls which we used for many purposes, there was a very strong feeling amongst the amateur Thespians that the Circe centre should not cater for theatrical performances in the usual Grand Hall. This hall was usually far too big for the intimate type of show and the performance suffered in consequence. The time had come when an intimate theatre, seating, say, 850 to 1,000, should be provided, in addition to the Grand Hall, and designed solely as a theatre.

In the public halls which *had* to cater for theatrical performances the decoration should be on the dark side and not in very light colours: because when the curtain is up the light auditorium picked up and reflected the light from the stage, which was quite wrong. When the curtain was up the auditorium should, as near as possible, disappear.

In regard to schools, here again it was anticipated that the cinema would play a very big part in education after the war, and a properly equipped cinema and theatre in the larger schools should be provided—*not* a universal hall with a flat floor, which is a gymnasium one moment and a theatre the next. It need only seat about 500 to 750. After all, the school play could be given on several evenings instead of one gigantic performance.

America was far ahead of us here, and several of their "colleges" and schools had theatres that in many cases were more efficient, not only in lighting but also in every respect, than some of the American theatres.

Mr. F. P. BENTHAM (*communicated*): It seemed to him very necessary to install some stage lighting equipment in the assembly hall of every school. The vital form of education provided by the drama and its associate craft—scene construction, painting, dressmaking, etc.—was at last recognised.

In the multi-purpose public hall the conflict between the requirements of musical and dramatic performances was evident; the former, with its large proscenium opening, stepped stage, and no wings, contrasting with the smaller proscenium and large wings of the latter. The rostrums used to enlarge the stage and provide the steppings for choir could be transferable to the rear of the hall to improve the sight lines for the drama.

In lighting a concert, the orchestra and choir must be able to read their scores and see the conductor's slightest movement; the view the audience gets is quite a secondary consideration. Individual lamps on the music desks, essential in the theatre, were a confession of failure on the concert platform.

He could not agree with Mr. Souter that battens with colour circuits provided basic stage lighting. For school, public hall, and theatre, a collection of individual spotlights and floodlights are an essential basis. These spotlights should not be confused with the big following spots (still known as "limes") common to variety theatres. Floods and spots were necessities, footlights and battens were half-way down the list, and "limes" at the bottom. As a general principle, stage lighting had to conceal more than it revealed. One piece of scenery and floods and spots = a complete setting; one piece of scenery + battens and footlights = one piece of scenery. Colour lighting produced from three or four colour sources should only be indulged in when plenty of money was available, a good dimmer board came before that. All halls should have a flat rear wall to the stage, free of doors, pipes, and radiators. This (finished matt white) bestowed the priceless gift of a cyclorama on the lucky hall.

In lighting the auditorium great care must be taken to avoid the solemn atmosphere created by most modern lighting systems, particularly when high up in the roof. This hall would be the scene of jolly plays, music, and dances, as well as tragic political meetings.

Mr. W. T. F. SOUTER, in reply, thanked the speakers for their interesting contributions to the discussion, and in view of the lateness of the hour dealt briefly with several of the points which had been raised, promising a more detailed reply in the printed version of the discussion.

The statistics mentioned by Mr. C. W. M. Phillips in connection with school lighting were very informative, and his recommendation that a Study Group should be set up to consider this matter is worthy of serious consideration. The author was not aware of any official survey of lighting standards in our Elementary Schools, although some views on this matter were expressed by the Board of Education in an Educational Pamphlet entitled "Elementary School Buildings." He recalled that Mr. Weston, on behalf of the Industrial Research Board, had conducted some interesting classroom tests which confirmed the scientific relationship between illumination and perception. School children were employed in

discrimination tests of mathematical symbols, and an average of their performances under different values of classroom illumination established a progressive improvement in visual acuity up to and beyond 50 ft.c. With reference to the proportion of the school service charges which can be attributed to lighting, the author had seen statistics to the effect that the cost of the lighting installation in certain Elementary Schools was 3 per cent. of the total capital expenditure, and the running costs had a similar relationship to the total overhead charges.

While agreeing with Mr. Burnett that we must be sure that any proposed school lighting regulations would in fact safeguard the eyesight of school children, the author stressed that higher lighting standards were not advocated for the express purpose of intensive or high speed education, but rather to approach, as far as was economically possible, the quality of daylight which would allow the eye to perform schoolroom tasks with the minimum effort.

Mr. F. C. Smith had expressed this viewpoint in a very able manner, and the author agreed that there are other important factors to be considered, even though they cannot be accurately assessed, apart from educational progress. Mr. Smith had also drawn attention to an important factor in classroom design—ceiling height—which could materially limit or increase the scope of natural or artificial lighting development.

The views expressed by Mr. George Smith in regard to the lighting of Museums and Libraries were particularly interesting, having regard to his wide experience on the subject, and he agreed that long tubular light sources having low surface brightness were eminently suitable in Libraries and Catalogue Rooms, where the bookstacks extended to the ceiling. The problem was rather different from the open-access Library, in which the bookstacks rarely exceeded a height of 7 ft. With reference to the high illumination values recommended for Operating Theatre tables it must be remembered that the light obstruction of the surgeon's hands and instruments may be as high as 50 per cent., and that further light losses will be occasioned by the cavity of the wound. When we consider that 80-90 per cent. of the incident light which ultimately reaches the operating point is absorbed, it will be appreciated that the resultant brightness bears little relation to the unobstructed illumination. It is reasonable to assume, however, that a lighting system affording the maximum diffusion and least light obstruction in the operating area would achieve the same effective illumination with a lower initial intensity. The two examples quoted by Mr. Ackerley rather supported this viewpoint.

He was glad to hear from Mr. E. Stroud that the paper had expressed the views of the Select Panel, of which he was chairman, and thanked him for his contribution to the discussion.

Replying to Mr. R. O. Ackerley on the subject of general lighting in the operating theatre, he referred to investigations which had proved that excessive brightness difference in the field of view reduces the visual performance and causes eye fatigue through continual changes of adaptation. The value of 30 ft.c. had been recommended to ensure that the brightness of the surroundings should not be less than 10 per cent. of the average value in the operating area, a ratio which is generally accepted as good practice in illumination design. These conditions are also desirable to enable assistants to perform their various duties with efficiency in all parts of the theatre.

He agreed with Mr. Ackerley that the illustration of blackboard lighting was not entirely satisfactory, and suggested that the apparent whiteness of the board was probably due to spread reflection from a partially specular surface, or diffuse reflection from chalk particles engrained in the surface of the blackboard. In regard to staircases, directional lighting from the head of the stairs would undoubtedly provide the best contrast between treads and risers, but it would be difficult to avoid obscuring shadows when persons descended the flights. Light sources at the top and bottom of each flight would eliminate such shadows, but care should be taken in the selection and siting of fittings to provide a noticeable difference in brightness between the treads and risers. A pattern or contrasting colour on the front edge of the tread was undoubtedly the best method of attaining clear definition of the steps under both daylight and artificial lighting conditions.

With reference to the value of illumination in art galleries, the author had quoted the recommendation made by the Select Panel who had investigated the existing data on this subject. The recommendation gave guidance for average conditions, but the final assessment of the most suitable illumination in any particular art gallery would necessarily be influenced by the average

reflection factor of the exhibits and other local considerations.

In reply to Mr. L. G. Applebee, he stated that the time factor alone had prevented him from dealing with swimming baths and other important aspects of the subject. He agreed that most indoor baths were used for other social activities during a considerable part of the year, with the result that the lighting system was usually of a general purpose nature. Practical considerations of accessibility and safety, when the baths were in use, influenced the design of the installation, however, and laylights or ceiling fittings with access from above were favoured for these reasons. The author expressed the opinion that the disadvantages mentioned by the speaker in regard to underwater lighting were more than offset by the attractive display and safety factor it afforded. For instance, persons on the high diving-boards could clearly see that the pool was clear of swimmers before diving, and baths attendants could more easily discern any irregularity or danger.

The contribution by Mr. Applebee and Mr. Bentham on the subject of stage lighting technique and the factors influencing its full appreciation were both interesting and informative.

Mr. F. P. Bentham had perhaps taken a very literal interpretation of the text concerning stage lighting equipment, as the author had not intended to imply that spotlights and floods were non-essential items. He agreed that in the lighting of public halls a solemn atmosphere should be avoided, but in lofty halls it had been his experience that pendant fittings with long suspension were more prone to promote a gloomy aspect in the upper part of the hall than was the case with close-ceiling fittings.

Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

CORPORATE MEMBERS:—

Asdell, J. H. .....110, Selly Park Road, BIRMINGHAM, 29.
Barnett, W. G. .....Barnett and Sons, Ltd., 118, High Street, BURTON-ON-TRENT.
Boley, A. E. .....Willow Cottage, Dundry, Nr. BRISTOL.
Chadwick, J. W. .....Electron Works, Pitt Street, SHEFFIELD.
Charlton, A. E. .....16, Longton Grove Road, WESTON-SUPER-MARE.
Corton, W. .....230, Kimberley Road, LEICESTER.
Culling, A. D. .....Stradella Glynde Road, Bexley Heath, KENT.
Duke, E. M. .....30, Rutherford Road, Windle, ST. HELENS.
Fletcher, A. E. .....21a, Derby Street, BURTON-ON-TRENT.
Graham, N. .....Upperhead Mills, Upperhead Row, HUDDERSFIELD.
Hinchcliffe, N. .....Yew Tree, Shepley, Nr. HUDDERSFIELD.
Holland, J. .....28, Commercial Street, HUDDERSFIELD.
Jamieson, W. B. .....5, Trenance Drive, Saltaire, Shipley, YORKS.
Keep, C. J. .....9, Camps Lane, SHEFFIELD, 1.
Lewis, H. .....47, Thorncliffe Lane, Chapeltown, YORKS.
Lightbown, J. .....75, Hinckley Road, Nuneaton, WARWICKSHIRE.
Littlewood, H. .....c/o British General Electric Co., Ltd., C/1 Loveday and Anderson Street, JOHANNESBURG, SOUTH AFRICA.
Mears, T. W. .....40, Blue Bell Avenue, Moston, MANCHESTER, 10.
Mills, F. E. .....16, Broadweir Road, Cwmbrau, Newport, MON.
Preston, H. .....43, York Place, LEEDS.
*Pryce-Jones, H. .....Electric House, Castle Square, BRIGHTON, 1.
Ripley, G. .....5, Sunny Bank Road, Edgerton, HUDDERSFIELD.
Robinson, W. .....40, Bradford Road, Brighouse, YORKS.
Seddon, W. A. .....63, Scalpcliff Road, BURTON-ON-TRENT.
Singlehurst, A. J. .....The British Thomson-Houston Company, Limited, Watford, HERTS.
Taylor, N. .....c/o F. W. Taylor and Son, Ltd., Albion Works, Milnsbridge, HUDDERSFIELD.
Thornton, J. T. .....11, George Avenue, Birkby, HUDDERSFIELD.
Walker, H. L. .....Protector Works, Elland, YORKSHIRE.
Walton, H. .....Strathdene, Station Road, Shepley, Nr. HUDDERSFIELD.

ASSOCIATE MEMBERS:—

Spencer, J. .....35, May Street, DERBY.
Thompson, V. M. ...“Top Meadow,” Killis Lane, Kilburn, DERBY.
Willatt, H. R. .....17, Lime Avenue, Breadsall, Nr. DERBY.

* Representative of Brighton Electricity Undertaking (Sustaining Members).

THE SKY FACTOR VALUE OF WINDOWS

By P. J. WALDRAM, F.S.I. *(Fellow)*

(Communicated)

A century or two ago, when it was possible to feel reasonably sure of the maximum degree of future external obstruction to windows by neighbouring buildings, architects amply proved their ability to practice the art or science of true fenestration, i.e., the design of windows to light interiors properly and not merely as external ornaments.

The results which they achieved in Georgian town houses, facing obstructions more or less standardised by custom, are to-day still an inspiring delight and an invaluable criterion of good natural lighting.

With the advent of high buildings, unrestricted by town planning, or by a law of private rights of light wholly uncertain in its incidence, the lighting efficiency of a window was reduced to a matter of unpredictable chance, and architects had therefore every excuse for ceasing to be interested in it.

Signs are now beginning to multiply of a lively anticipation that compulsory town planning will, in the post-war period, operate throughout the country, and will be similar in form to that at present in force over the London County Council area. Under this the maximum degree of external obstruction which will in the future be permitted over the aspect of any window, and for which therefore that window should be designed, can be predicted with reasonable ease and certainty in conveniently simple terms of height and distance; and architects obviously recognise that as soon as this comes about they will inevitably be required by their clients to design windows for lighting capacity and not only, as heretofore, for appearance.

Of a recent series of lectures at the R.I.B.A. on architects' problems in post-war design no fewer than three were devoted to the natural lighting of interiors. In the last lecture it was suggested that lists of steel windows of standard dimensions, accompanied by tables showing the floor area which they would be capable of lighting efficiently to various degrees of adequacy under different degrees of obstruction, should enable architects to design windows for lighting performance with the same facility as they customarily select from tables the scantlings of wood floor joists. The lecturer stated that it was hoped that the N.P.L. would publish such tables shortly.

They would be very valuable in attracting and focusing attention upon a subject which has been unduly neglected, whether they fulfil or not the optimistic forecast of the lecturer. No indication was given of their probable scope, which would require to be large if they are to cover even a portion of the conditions which obtain in ordinary practice.

Under the restrictions to overbuilding which are operative over the L.C.C. area, any one standard window is liable, according to the locality in which is situated the building which it serves to find itself faced, now or in the future, with one of several different degrees of obstruction defined by at least three maximum permissible building heights at distances governed by different limiting angles.

If the object of the tabulation is, as it should be, to assist architects to design windows for lighting efficiency in face of the maximum obstruction with which such windows may be faced under town planning, it would require to be sufficiently voluminous to include the performance index or indices of each standard window (and there are many) under all possible degrees of permissible obstruction; and this must, of course, be varied for different floor levels, to which the effect of any given obstruction varies materially.

The possibilities of applying tabulated data to practical problems in design is limited by the fact that no tabulation, however voluminous, can do more than apply to, and can only be correct in relation to, specific heights of window head. Even if architects were content to adopt

always standardised window dimensions, which is unlikely, they can scarcely be expected to adhere invariably to the storey heights and window head heights for which the tabulated values are calculated, and if true fenestration is to be practised many windows, possibly the majority of windows, will require to be treated on their merits.

Possibly with this in view the same lecturer described three methods which have recently been suggested of computing the daylight factor value (it should, of course, have been the sky factor value) of windows, either obstructed or unobstructed, at different distances, as alternative to the simple and accurate, but sometimes tedious, graphic method of calculation recommended in the well-known D.S.I.R. report on the penetration of daylight and sunlight into buildings. (1)

The first of these is the Dufton window scale described in the issue of "The Transactions" for March last (Vol. VIII., 3, 61), which purports to give, with the aid of a simple geometrical construction on a drawing, the sky factor value per foot in width of window. The second was an Alignment Chart devised by Dr. J. W. T. Walsh with the same object, but not published.

Any architect who has used the customary graphic method of computing sky factors with a measuring diagram will appreciate at once that these methods cannot be other than approximate, because the sky factor value per foot in width of any window with a horizontal head is not a constant quantity. The lecturer described them as being reasonably accurate for narrow windows, but no particulars were given of the extent of error involved in their use. The alignment chart was described as being only applicable to unobstructed windows and to positions back from the centre line of the window; but, as will be shown later, values at positions off the centre line and over horizontal obstructions could, if necessary, be deduced from the information which it supplies.

The third method described consisted of the two valuable new formulae published by Mr. T. Smith in the June issue of "The Transactions" (Vol. VIII., 6, 110), conveniently accompanied by graphs

(1) D.S.I.R. Illumination Research. Tech. Paper No. 7. 2nd Ed. (H.M.S.O. 9d.)

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.016	.020	.023	.024	.024	.025	.026	.027	.027	.028	.028
.018	.022	.026	.027	.027	.028	.028	.029	.030	.031	.031
.019	.022	.025	.026	.027	.028	.029	.030	.031	.032	.032
.019	.022	.026	.027	.028	.029	.030	.032	.033	.034	.034
.019	.022	.026	.027	.029	.031	.032	.033	.034	.036	.036
.019	.023	.028	.029	.031	.034	.035	.036	.037	.038	.040
.020	.024	.029	.031	.032	.034	.035	.036	.037	.039	.040
.020	.026	.028	.031	.032	.034	.035	.037	.038	.039	.040
.020	.026	.029	.032	.034	.035	.037	.038	.040	.041	.042
.019	.024	.028	.029	.031	.033	.035	.037	.039	.041	.041
.018	.024	.026	.028	.030	.032	.034	.035	.037	.039	.040
.017	.023	.025	.026	.027	.029	.032	.034	.035	.037	.038
.015	.019	.023	.025	.026	.028	.029	.031	.032	.034	.036
.014	.018	.021	.023	.024	.025	.026	.027	.029	.030	.030
.010	.016	.017	.018	.019	.021	.022	.024	.024	.025	.026
.007	.009	.010	.011	.012	.013	.014	.014	.015	.016	.017
.005	.007	.008	.009	.010	.012	.012	.013	.014	.014	.015
.001	.001	.002	.002	.002	.003	.003	.003	.004	.004	.004

20 ft.

10 ft.

Fig. 1. Values of sky factors on horizontal table plane at cill level per square foot of unobstructed window 16 ft. distant.

showing the extent of error involved by their use.

Unfortunately, architects have a rooted, if unreasonable, dislike to the introduction into design of mathematical formulae, and it may therefore be timely to recall that at a conference of lighting engineers held in Paris in 1937 a paper was read describing a very simple method of short-circuiting accurately the labour involved in the usual graphic method of calculating from measuring diagrams. A summary in English of the material portions of the paper appeared in the "Builder" of October 1, 1937, but the conference generally was not reported in this country.

The paper included tabulations, of which Fig. 1 is an example, of the calculated sky factor values per square foot of unobstructed window opening, glazed and unglazed, at various distances back on the centre line of a window 21 ft. wide and 20 ft. high. It was expected that these dimensions would cover all ordinary cases, but they could be increased if necessary. The tabulations were made on grids drawn to scale, and it was suggested that on tracing paper over such grids an architectural draughtsman could readily plot from plan and section a projection of any window and of whatever could be seen through it from any position, whether sky or obstruction, and obtain the net sky factor value at that position by summating the values comprised in any patch of unobstructed sky, without further calculation.

In spite of its simplicity the method failed in practice to effect any material economy of time over the various labour-saving devices used in connection with the graphic method by those who frequently had occasion to calculate sky factors. The reason for recalling it is that the numerous tabulations when once made and checked provide a convenient accurate basis for the compilation, by simple addition, of graphs such as Figs. 2 to 8 by which material information can be presented in any alternate form desired.

Graphs have important advantages over tabulated data. The information which they afford is complete, obvious and comparative, instead of being scattered over pages of figures; and they are therefore more attractive, or less distasteful, to architects, who after all will eventually have the last word in fixing the dimensions of post-war windows. More important are the greater facilities for interpolation which are presented by graphs, and therefore the greater probability of being able to cope with the infinite variety of practical conditions.

As Figs. 2 to 8 only give the sky factor value of unobstructed windows at varying distances back on the centre line, they would appear to be insufficient for the preparation of sky factor contours giving the areas lit to any given degree of adequacy by ob-

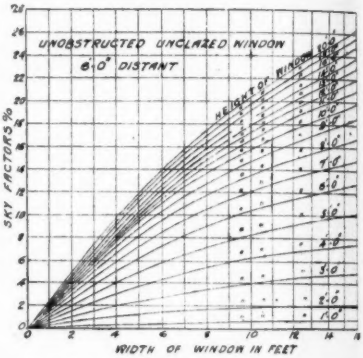

Fig. 2. Illumination in Sky Factors on Horizontal Table Plane at Cill Level from unobstructed unglazed Window 6ft. distant.

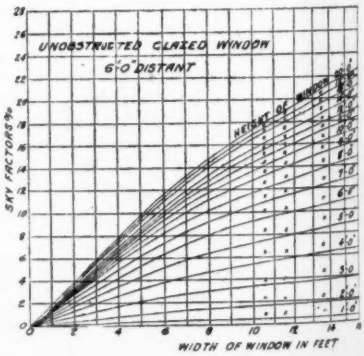

Fig. 3. Illumination in Sky Factors on Horizontal Table Plane at Cill Level from unobstructed glazed Window 6ft. distant.

structed or unobstructed windows such as Fig. 9, which indicates the efficiency of an unglazed window opening 3 ft. wide and 6 ft. high above the reference plane both unobstructed and also under the typical suburban condition of a ground floor window with its head 10 ft. above ground level facing the obstruction of a continuous permissible building height of 40 ft. at a distance of 80 ft.

By one of the two formulae already referred to devised by Mr. T. Smith, it is possible to calculate the position of points on any desired contour for windows which are either unobstructed or facing an obstruction of known height and distance. Useful, and even invaluable, as this may be in the compilation of data, post-war problems in fenestration cannot hope to escape the difficulties involved by irregular obstructions which can only be solved by the tedious, if simple, process of measuring geometrical projections set out on diagrams. Under this contour plans have hitherto been set out by adopting the methods used by surveyors in the preparation of contours of land levels.

A grid of lines is laid down on the ground, and from spot levels taken at the intersections of the grid, sections are plotted along the lines, if necessary in two directions. On these sections the position of points at the level of the required contours is ascertained and transferred to the plan, where they are joined up to form contour lines. Sky factor contours are drawn similarly from the measured or calculated sky factor values at the intersections of a grid of lines on a plan of the room or area lit, generally 2 to 4 ft. apart, as in Fig 9.

Consider the sky factor value at the intersections Ic. These are 6 ft. back from the window, 2 ft. to the right or left of the centre line, and 6 ft. 6 ins. beyond the reveals of the window. The sky factor value of each would therefore be half that of a window 7 ft. wide, less half

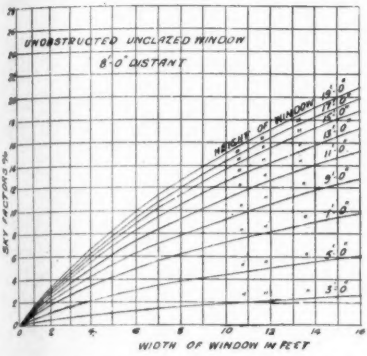

Fig. 4. Illumination in Sky Factors on Horizontal Table Plane at Cill Level from unobstructed unglazed Window 8ft. distant.

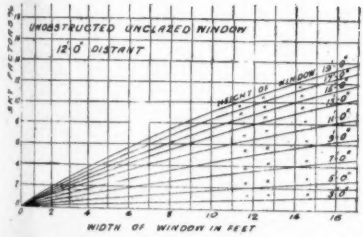

Fig. 5. Illumination in Sky Factors on Horizontal Table Plane at Cill Level from unobstructed unglazed Window 12ft. distant.

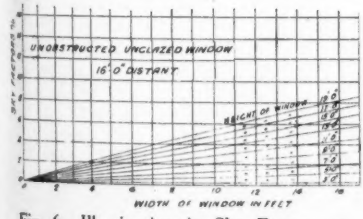

Fig. 6. Illumination in Sky Factors on Horizontal Table Plane at Cill Level from unobstructed unglazed Window 16ft. distant.

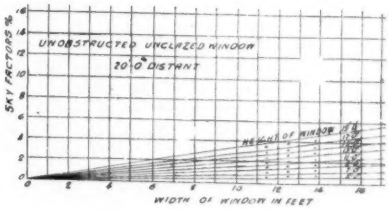

Fig. 7. Illumination in Sky Factors on Horizontal Table Plane at Cill Level from unobstructed unglazed Window 20ft. distant.

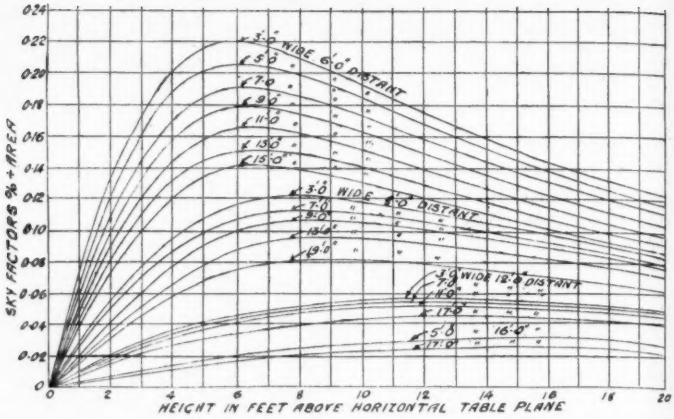

Fig. 8. Illumination on Horizontal Table Plane at Cill Level in Sky Factors per square foot of unobstructed unglazed window openings.

that of a window 1 ft. wide. This would also be true for all intersections on line 1, viz., Ia, Ib, Id, etc. Similarly the sky factor value for all intersections on line II would be half the difference between windows 11 ft. and 5 ft. wide, and for intersections on lines III, IV, and V half the difference between windows 15 ft. and 9 ft., 19 ft., and 13 ft. and 23 ft. and 17 ft. wide respectively.

The last-named is beyond the scope of the graphs illustrated, which were set out mainly with regard to the lighting at the back of rooms, and must be regarded as merely illustrative for the purpose of setting out complete contour plans.*

As closely as the small-scale reproduction of the graph Fig 2 can be read, the sky factor value of a window 7 ft. wide, 6 ft. high, and 6 ft. distant is 8.2 per cent., and that of a window 1 ft. wide 1.2 per cent. Half the difference would be 3.5 per cent. As measured from window areas projected on to a measuring diagram the value was 3.43 per cent. By the Smith formula, admittedly and even intentionally conservative, it was slightly less.

The effect of a horizontal obstruction across the whole aspect of a window is merely that of raising the cill level as viewed from the reference point by a certain height ascertainable by drawing on a section to scale a line from the reference point to the top of the obstruction and noting where it cuts the plane of the window, or more speedily by calculation. Thus a line from any point 6 ft. distant from the window to the top of an obstruction 30 ft. above the window head and 36 ft. above the

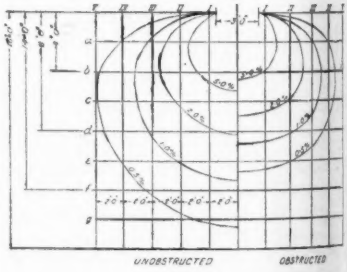

Fig. 9.

*Since this article was written the writer has adopted with advantage the suggestion of plotting the sky factor values of half windows up to 40 ft. in width, this doubling the scope of the graphs for contour plans. He has also greatly reduced the labour of producing them by graphing the sky factor values of the area on the measuring diagram of quadrilaterals enclosed between two pairs of co-ordinates of angles of bearing and elevation. It is hoped that a set of the new graphs may be completed and published shortly.

reference plane at cill level, and 86 ft. distant would intersect the window plane at 36 x 6/86 = 2.5 ft. above the reference plane. The obstructed sky factor value at Ic is therefore half the difference between two windows 7 ft. wide and 1 ft. wide, both 6 ft. high and between two similar windows, both 2.5 ft. high, or $3.5-\frac{(2.4-0.3)}{2}=3.5-1.05=2.45$

This agrees exactly with projected areas measured on a diagram, the value by the Smith formula being, as before, slightly less.

The calculation of sky factor values at the seventy-seven intersection points of the somewhat unusually close grid shown in Fig 9 by projecting and measuring window areas on a measuring diagram entailed nearly a day's work by a draughtsman not unaccustomed to labour-saving devices. Comparison of these values with those given by the Smith formula, although tedious, was far more speedy but a similar check from large scale graphs entailed not much more than minutes of work in place of hours.

As neither graphs nor formulae can be applied to the irregular obstructions which are inseparable from practical problems, it is distinctly fortunate that work in connection with them can be very materially reduced by photography (2), and by simple sky factor gauges, which, if of necessity home made owing to war conditions, are not necessarily in any way inaccurate (3).

The modern technique of measuring and predetermining daylight was evolved to assist the Courts in the adjudication of disputes over legal rights, which are strictly confined to light adequate for ordinary purposes only. It should not be assumed too readily that units of measurement and standards which have proved reliable for such threshold adequacy are also applicable to the higher values required for industry, and are material to good fenestration.

The eye is a most capricious organ. So many of its reactions are psychological that the peculiar knowledge and experience of architects may well prove to be more helpful than mathematical calculations. Certainly in the XVIth and XVIIth centuries architects had no scientific assistance in their excellent work (4).

(2) "The Use of Photographs in Town Planning and Design." (P. S. King and Sons. Reprinted articles from the Journal R.I.B.A. 2s. 6d.)

(3) "Daylight Illumination in Factories and Workshops." (Trans., Jun. Inst. of Engineers, 39, Victoria-street, S.W.1. Vol 53, 3. Reprint, 1s. 6d.)

(4) "The Lost Art of Fenestration." ("Builder," January 23, 30; February 6, 1942.)

Exchange of Publications between British and American I.E.S.

An arrangement for an exchange of publications has been entered into between the Illuminating Engineering Societies in Great Britain and in the United States. This arrangement provides that the *Transactions* and *Light and Lighting* shall be sent, as soon as issued, to the eight "Regions" of the American Society, whose publication, *Illuminating Engineering*, is to be sent from now onwards to the secretaries of the Area Committees in Gt. Britain, so that they may be filed for reference by members. It is hoped that this welcome arrangement will be helpful in enabling members of each body to become familiar with the other's activities.

Formation of new I.E.S. Group in Huddersfield

Members will be interested to learn that a new group, operating in the North Midland Area, has now been formed in Huddersfield.

Preparations for forthcoming meetings are already being made, and members in the district will receive particulars in due course.

Officers and committee have been elected as follows:—

Chairman.—Dr. J. Whitaker.

Hon. Secretary.—E. Wood.

Committee.—Messrs. R. Hardy, E. Lunn, H. P. Ripley, W. Robinson, H. Singleton, J. T. Thornton, W. Turner, and H. L. Walker.

Sessional Meetings in London

STREET LIGHTING SPECIFICATIONS OF THE FUTURE; SHOULD THEY BE BASED ON THE DESIGN OF THE UNIT OR THE EFFECT OF ILLUMINATION?

A Sessional Meeting was held at the Institution of Mechanical Engineers (Storey's Gate, London, S.W.1) on Tuesday, December 14, 1943. The chair was taken by the President (Dr. H. Buckley), who in opening the proceedings extended a welcome to members of the Association of Public Lighting Engineers, with whom this joint meeting had been arranged.

The minutes of the last meeting having been taken as read, the President called upon Dr. S. English and Mr. R. Maxted to introduce contributions on "Street Lighting Specifications of the Future: Should they be Based on the Design of the Unit or the Effect of Illumination?" In doing so he remarked that the subject was a very debatable one. Dr. English and Mr. Maxted had consented to put forward opposite views thereon, and it should be understood that neither they, nor any others who took part in the discussion should be taken to task in the future for any views expressed on this occasion.

Dr. English and Mr. Maxted then opened the discussion in which the following took part: Mr. E. J. Stewart, Mr. T. Wilkie, Mr. J. M. Waldram, Mr. W. J. G. Davey, Mr. F. L. Cator, Mr. E. Stroud, Mr. J. A. Prowse, Mr. H. H. Ballin, and Mr. F. C. Smith.

Dr. English and Mr. Maxted briefly replied to the discussion, and a vote of thanks to the authors terminated the proceedings.

Meetings of Centres and Groups

THE AUTOMATIC CONTROL OF STREET LIGHTING BY SUPERIMPOSED HIGH FREQUENCY WAVES.

At a meeting of the Glasgow Centre, held on November 24, 1943, a lecture on the above subject, supplemented by demonstrations, was given by Mr. W. F. Phillips.

Mr. J. H. Scott, in opening the meeting, invited Mr. J. Dickson to take the chair for the current session. A vote of thanks to Mr. Scott for his services during the past year was carried with acclamation.

Mr. Phillips then introduced his subject by a brief reference to the historic development of automatic control equipment, and discussed the merits of methods based on vibrating reeds, electro-mechanical devices, and polarised relays. The lecturer showed how a polarised relay could be designed to respond to a high-frequency wave superimposed upon an ordinary net work. Reference was made to the multitude of parasitic frequencies inherent in all networks, but it was emphasised that a relay would only respond to a combination of the correct frequency *plus* the correct timing. Such a device obviously gave accurate control of a very flexible nature which could be applied to at least twenty-four different circuits. A series of lantern slides illustrated methods of injecting impulses into a high-tension network by series of parallel means. Present-day practice was reviewed and an indication of future possibilities given. The audience of some seventy-five members and visitors included Mr. A. Cunnington (Past President), who was given a cordial welcome.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form :—"Trans. Illum. Eng. Soc. (London)."

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